NON-PUBLIC?: N
ACCESSION #: 8909050047
LICENSEE EVENT REPORT (LER)

FACILITY NAME: Palo Verde Unit 1 PAGE: 1 OF 16

DOCKET NUMBER: 05000528

TITLE: Ground Fault In 13.8 kV Bus Causes Fire in Unit Auxiliary Transformer And Reactor Trip
EVENT DATE: 07/06/88 LER #: 88-010-01 REPORT DATE: 08/28/89

OPERATING MODE: 1 POWER LEVEL: 100

THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR SECTION
50.73(a)(2)(i), 50,73(a)(2)(iv), & 50.73(a)(2)(x)

LICENSEE CONTACT FOR THIS LER:
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COMPONENT FAILURE DESCRIPTION:

CAUSE: X SYSTEM: EA COMPONENT: NSBU MANUFACTURER: G080
X EA XFMR W005
X BI HCV L200
X SB HCV D263

REPORTABLE NPRDS: N
Y
Y
Y

SUPPLEMENTAL REPORT EXPECTED: NO

ABSTRACT:

On July 6, 1988, Palo Verde Unit 1 was in Mode 1 (POWER OPERATION) at approximately 100 percent power when the reactor tripped on a Low Departure from Nucleate Boiling Ratio (DNBR).

The non-class 1E 13.8 kV bus 1E-NAN-S02 faulted to ground exacerbating an existing weakness in the Unit Auxiliary Transformer causing the Unit Auxiliary Transformer to rupture and catch fire. This caused a loss of electrical power to the Reactor Coolant Pumps initiating the low DNBR trip. The reactor was stabilized in Mode 3 (HOT STANDBY) on Natural Circulation. A Notification

of Unusual Event (NUE) was declared at 1215 MST due to the fire. The fire was extinguished and the NUE terminated at 1221 MST.

At 1303 MST an attempt was made to reenergize the faulted bus 1E-NAN-S02 and a fire started in the switchgear. An NUE was declared due to the fire and loss of non-class 13.8 kV electrical power. This fire was extinguished at 1322 MST.

Following visual inspections, cleaning, and meggering, IE-NAN-S01 was reenergized at 1749 MST. Reactor Coolant Pump 1A was started at 0033 MST on July 7, 1988, and forced circulation was reestablished. The NUE was terminated at 0102 MST on July 7, 1988 and a cooldown was commenced.

Corrective actions taken to prevent recurrence include the rework of bus 1E-NAN-S02 and the replacement of the Unit Auxiliary Transformer.

END OF ABSTRACT

CAUSE: X SYSTEM: EA COMPONENT: B52 MANUFACTURER: G080

REPORTABLE TO NPRDS: Y

I. DESCRIPTION OF WHAT OCCURRED:

A. Initial Conditions:

On July 6, 1988, Palo Verde Unit 1 was in Mode 1 (POWER OPERATION) at approximately 100 percent power.

B. Reportable Event Description (Including Dates and Approximate Times of Major Occurrences):

Event Classification:

Event or condition that resulted in manual or automatic actuation of any Engineered Safety Feature (ESF)(JE) including the Reactor Protection System (RPS)(JC). Event that posed an actual threat to the safety of the nuclear power plant or significantly hampered site personnel in the performance of duties necessary for the safe operation of the nuclear power plant including fires, toxic gas releases, or radioactive releases. Operation or condition prohibited by the plant's Technical Specifications.

At approximately 1208 MST on July 6, 1988, a phase B to ground fault occurred on non-class 1E 13.8 kV bus (BU)(EA) 1E-NAN-S02. This fault ionized the air in the immediate vicinity causing all three phases to short to ground. The feeder breakers (BKR) (EA) to non-class 1E buses 1E-NAN-S01 and 1E-NAN-S02 did not trip immediately because they trip on a time overcurrent protection scheme. The overcurrent protection on these breakers is set to trip in .7 second (42 cycles) on a three phase bus fault, corresponding to a 24000 Ampere fault. The Unit Auxiliary Transformer (UAT)(XFMR)(EA) started to fail at 12 cycles and ruptured, ignited, somewhere between 17.5 and 20.5 cycles which caused, the 1E-NAN-S01 and 1E-NAN-S02 supply breakers, as well as the generator (GEN)(TB) output breakers, to open due to the transformer "sudden overpressure". Due to the loss of the transformer, electrical power was lost to the Reactor Coolant Pumps (RCP)(AB) which caused a reactor trip on Low Departure from Nucleate Boiling Ratio (DNBR). The low DNBR trip was due to the RCP's speed decreasing below their setpoint. The Fast Bus Transfer (FBT) did not take place during this event. The sync-check relay checks voltages on 1E-NAN-S03/S04 and on 1E-NAN-S01/S02 and completes the transfer if both buses are in sync and have the required voltages. In this event, 1E-NAN-S01 and 1E-NAN-S02 bus voltage sensed by the sync-check relay was below the minimum value. At 14.5 cycles into the event the FBT signal was initiated but was not completed because 1E-NAN-S01 bus potential was zero due to the UAT failure and 1E-NAN-S02 bus potential was zero due to the 1E-NAN-S02 bus fault.

The event was diagnosed as a Loss of Forced Circulation and the Control Room staff (utility, licensed) entered the appropriate recovery procedure 41RO-1ZZ04 (Loss of Forced Circulation). The Control Room staff responded appropriately using the correct Abnormal and Recovery Operating Procedures. A Notification of Unusual Event (NUE) was declared at 1215 MST due to the fire in the UAT. The reactor (RCT)(AC) was stabilized in Mode 3 (HOT STANDBY) at approximately 1230 MST. There were no automatically initiated Engineered Safety Feature Actuation System (ESFAS)(JE) actuations, and none were required.

Secondary heat removal was maintained by Operator action utilizing Atmospheric Dump Valves (ADVs)(SB). The secondary operator observed that ADV SGB-HV-179 exhibited erratic control response and did not use it after the initial attempt. The ADVs SGA-HV-178 and

SGB-HV-185 were utilized to maintain an adequate secondary heat removal rate throughout the event and subsequent cooldown to Shutdown Cooling Entry. The Main Steam Isolation Valves (MSIVs) were closed after condenser vacuum was broken. The "B" train handswitch for MSIV-180 in the control room indicated dual position but was verified closed by local position indication. The "A" train handswitch for MSIV-180 in the control room indicated the valve to be closed.

The Pressurizer Level Control System (PLCS) functioned as designed. Minimum level was reached at 26% due to the Reactor Coolant System (RCS) cooldown. Primary operator action was required to stop letdown oscillations experienced due to flashing in the letdown line. This action was taken because the isolation valve (ISV), CHB-UV-523 (CB) did not close as expected on loss of Nuclear Cooling water flow to the Letdown Heat Exchanger (HX)(SB). Following closure of the letdown isolation valve, the pressurizer level started to increase due to normal charging flow which was maintained to assure adequate RCP seal cooling. Subsequently, the pressurizer level exceeded LCO 3.4.3.1 requirements and, therefore, ACTION b was entered at 1315 MST and exited at 1350 MST when pressurizer level was restored to less than 56 percent.

An Engineering Evaluation Request (EER) was initiated to evaluate this condition and identified a drawing discrepancy on the electrical elementary (13-E-CHB-013). This drawing shows contact point FSL-613 open in the deenergized state which would cause CHB-UV-523 to close on a loss of power. (FSL-613 is the low nuclear water flow interlock for CHB-UV-523 closure.) The FSL-613 contact actually defaults in the closed position on a loss of power. This causes the valve to remain open on a loss of power and to close on a restoration of power. A Plant Change Request (PCR) has been initiated to correct the wiring configuration of FSL-613 to allow CHB-UV-523 to close on a loss of power.

The Control Room was notified that a fire was in progress at the UAT and the Area 2 Auxiliary Operator (AO)(utility, non-licensed) proceeded to his area to check equipment and saw smoke at the southeast end of the Turbine Building. (Area 2 comprises the 100 foot and 120 foot levels of the Turbine Building.) The panel to verify deluge flow to the sprinklers (SRNK)(KP), for the transformers is located inside the wall that was damaged by the explosion making it unsafe for flow verification. Therefore, the Area 2 AO proceeded to activate the deluge valves to all

transformers and quickly left the area. Flow was then verified at the sprinklers of the various transformers. The deluge system is activated by the electrical portion of the fire protection system that was lost due to the transformer failure. There is no DC backup for the fire panels in the Turbine Building as there is for the fire panels in the Auxiliary Building. The power supply to the deluge system is distribution panel (PL) E-QBN-D84D which is supplied from Essential Lighting Panel E-QBN-D84 (FG). E-QBN-D84 is supplied from Class 1E 480 volt Motor Control Center (MCC)(ED) E-PHB-M3217 which is supplied from 4.16 kv/480 volt Load Center (LC)(EB) E-PGB-L32C2. The load center is supplied from Class 1E 4.16 kv bus (BU)(EB) E-PBB-S04 which is normally supplied power from the Engineered Safety Feature (ESF)(EB) Transformer (XFMR) E-NBN-X04. Class 1E bus E-PBB-S04 can also be supplied from the Emergency Diesel Generator (EDG)(EK) or ESF transformer E-NBN-X03.

Fire protection personnel (utility, non-licensed) responded immediately when they heard the explosion. At 1221 MST the fire was reported out and the NUE was terminated.

At 1230 MST Train "A" and "B" Control Room Essential Filtration Actuation Signals (CREFAS)(VI) were manually initiated to restore ventilation to the Control Room since normal ventilation was not available due to loss of power. Control Room personnel knew that without non-class power the normal source of Instrument Air (IA)(LD) was not available and the nitrogen system (LK) should automatically provide the backup source of air. The Area 5 AO (utility, non-licensed) was directed to verify that the nitrogen supply was in service. (Area 5 comprises all levels of the Control and Diesel Buildings and all outside areas within the protected area except areas inside the radiological control fence.) The AO reported that everything was operating as expected at the nitrogen skid. A consequence of utilizing nitrogen to supply air operated valves (V) was the potential effect on habitability of the lower levels of the Auxiliary Building. It was reported that air in the lower levels of the Auxiliary Building was stale and breathing was becoming difficult. Unit wide announcements were made by Control Room personnel announcing the use of nitrogen and its possible effects. Radiation Protection personnel were notified that individuals entering the Auxiliary Building should be provided with oxygen

monitors. At 1655 MST Control Room personnel also manually initiated the Essential Fuel Building Ventilation system to the

lower levels of the Auxiliary Building to increase circulation and improve habitability.

At 1250 and 1254 MST, Emergency Diesel Generators "B" and "A" respectively (DG)(EK) were manually started and placed on-line to supply power to the Class 1E 4.16 kV buses (EB) 1E-PBB-S04 and 1E-PBA-S03. This action was taken as a conservative measure because the Engineered Safety Features (ESF) transformers were being sprayed from the deluge system and to protect the 4.16 kV class buses from the switchyard while attempting to reenergize the 1E-NAN-S01 or 1E-NAN-S02 buses. The class 1E 4.16 kV buses power supplies are from the startup transformers (XFMR)(EA) via buses 1E-NAN-S05, 1E-NAN-S03 and 1E-NAN-S06, 1E-NAN-S04 which also supply 1E-NAN-S01 and 1E-NAN-S02 respectively. The 1E-NAN-S05A breaker, which is the supply breaker for 1E-NAN-S03, could not be opened electrically from the Control Room or locally. The breaker had to be manually opened at the switchgear. The class 1E 4.16 kV buses were supplied power from their respective diesel generators and then isolated from the electrical distribution system to ensure they remained OPERABLE during reenergization of buses 1E-NAN-S01 and 1E-NAN-S02.

Protective Relaying and Control (PR&C) personnel were requested by Operations personnel to determine if 1E-NAN-S02 could be reenergized. PR&C and Operational personnel proceeded to the Switchgear (SWGR) room. Upon arriving in the switchgear room, the lights were out and the presence of smoke was detected. At that time it was believed that the smoke was coming from the UAT since the roll-up door which is on the east wall of the switchgear room was open to the area affected by the UAT fire. The only targets noted on the 1E-NAN-S02 bus were the Undervoltage Relays (27)(EA) due to the fact that the bus was deenergized. All trip flags were recorded and reset prior to reenergization. Based on this information it was thought that the 1E-NAN-S02 bus was fully capable of being reenergized. At 1303 MST an attempt was made to reenergize the 1E-NAN-S02 bus. However, after closing the breaker to energize the bus, the breaker tripped open and it was reported that the bus was on fire. At about the same time of the fire in 1E-NAN-S02 the Emergency Coordinator (utility, licensed) realized that he had misread the requirements for an NUE concerning loss of power to class and non-class 1E electrical loads. He misread it as a loss of class 1E and non-class 1E power requiring an NUE instead of a loss of class IE or non-class 1E power requiring an NUE. That is why the earlier NUE was terminated. At this time an NUE was declared again because of the fire and due to recognition of the fact that 13.8 kV non-class 1E electrical power was not available. The fire was extinguished at 1322 MST.

The non-class Nuclear Cooling Water (NC) system which provides coolant water to the RCP's was not available due to the loss of non-class electrical power. At 1336 MST the Essential Cooling Water (EW) system Train "A" was cross-tied to the non-class NC system train "A". Due to the EW/NC cross-tie the EW system was declared inoperable and the Technical Specification Limiting Condition for Operation (LCO) 3.7.3 ACTION was entered. This was determined to render Essential Chilled Water (EC) system inoperable per Technical Specification 3.7.6. The one (1) hour conditions of LCO 3.7.6 could not be satisfied since there was no normal Heating, Ventilating, Air-Conditioning (HVAC) available to the vital power distribution room due to the loss of non-class power. Therefore, the unit was in an ACTION statement that required the unit to be in Cold Shutdown within 30 hours.

While opening EW/NC cross-tie valve EWA-UV-145, a dual indication was noticed on the valve. An AO (utility, non-licensed) was directed to open the valve. Upon reaching the valve and after manually opening the valve approximately one half of a turn he could hear the flow thru the valve indicating that it had been shut. He then fully opened the valve.

During the performance of maintaining pressurizer level control, the primary operator isolated RCP seal bleed-off flow to minimize the pressurizer level decrease. He noted that three of the four flow indicators continued to indicate flow. After notifying the CRS, he then monitored VCT level in order to ensure the continued flow indications were indeed false (VCT level would be expected to remain stable with letdown isolated, RCP seal bleed-off isolated, and charging pumps off). After monitoring the VCT, he was satisfied that the indicators were just not reaching full downscale indication and he continued to monitor safety functions.

Surveillance Requirement 4.1.2.7.a.2.a was not performed within the required time limits. This Surveillance Requirement requires that the startup channel high neutron flux alarm be demonstrated OPERABLE within 1 hour of a reactor trip. The Control Room Supervisor (CRS) (utility, licensed) stated during an interview subsequent to the event, that when he reached step 5.17 in 41RO-1ZZ04 that stated to..."Perform Appendix A and B of 41OP-1ZZ08 (T.S. 3.1.2.7)", he noted that they were steps in an Operating Procedure (OP). Therefore, he didn't place as high a priority on performing the step in the Recovery Operating Procedure (RO),

as on the performance of other RO and AO procedure related tasks. At 1645 MST the surveillance test was performed and it was determined that channel "A" was inoperable and LCO 3.1.2.7 ACTION a.1 was entered.

Following visual inspections, cleaning, and meggering, 1E-NAN-S01 was reenergized at 1749 MST. Various plant equipment was energized at

1920 MST. At 1922 MST train "A" EW was isolated from train "A" NC and LCO ACTIONS 3.7.3 and 3.7.6 were exited. EW and EC were inoperable for 5 hours and 46 minutes. Diesel Generator "A" was paralleled with the normal power supply to PBA-S03 and unloaded. The diesel was shutdown at 2201 MST.

At 2310 MST, RCP 1A was restarted but tripped shortly thereafter. Operators performed a review of the cause of the trip. It was determined to be a speed sensor relay trip resulting in an 86 lockout. RCP 2A was then started, but also tripped as a result of the speed sensor relay.

Further investigation was performed by Operations personnel to determine the cause for a similar trip on separate RCPs. After reviewing the electrical prints for the RCPs it was determined that the voltage reduction on non-class 125 VDC bus (EI) 1E-NKN-M46 was enough to affect the accuracy of the Agastat relay (RLY) on the RCP that trips the pump if it is not greater than 600 rpm within 14 seconds. The Control Room staff had previously determined that the 'F' battery (BTRY) (EI) was, due to its low voltage condition, too great of a load on the battery charger (BYC) (EI) 1E-NKN-H18 and had decreased the charger voltage to stay within the charging parameters of the battery. To ensure and maintain adequate voltage on the 1E-NKN-M46 and enable an RCP start attempt, it was then decided to remove the battery from the battery charger and raise the charger voltage. When the battery was removed from 1E-NKN-M46, DC voltage was restored to normal levels and RCP 1A was successfully started. The NUE was terminated at 0102 MST on July 7, 1988 after the forced circulation was re-established. A Reactor Coolant System cooldown was commenced at 0112 MST on July 7, 1988.

Power to the RCPs was lost due to the deenergization of 1E-NAN-S01 and 1E-NAN-S02. The Control Room staff recognized the impact on the capability to maintain forced circulation. Investigation has determined the Control Room staff did not identify the need to

enter the ACTION, and did not log the entrance into LCO 3.4.1.2 ACTION b for "no Reactor Coolant loop in operation...". NOTE: There is no guidance within 41RO-1ZZ04 (Loss of Forced Circulation) denoting the entrance into LCO 3.4.1.2. The Control Room staff complied with the ACTION fortuitously and immediately initiated "...corrective action to return the required Reactor Coolant loop to operation". LCO ACTION 3.4.1.2.a was entered and 3.4.1.2.b was exited when RCP 1A was restarted at 0033 MST on July 7, 1988. LCO ACTION 3.4.1.2.a was exited when the Unit entered Mode 4 at 1323 on July 7, 1988. The ACTION was complied with at all times.

Diesel Generator "B" was paralleled with the normal power supply to PBB-S04 and unloaded. The diesel was shutdown at 0225 MST on July 7, 1988.

The unit entered Mode 4 (HOT SHUTDOWN) at 1323 MST on July 7, 1988 and Mode 5 (COLD SHUTDOWN) at 0546 MST on July 12, 1988.

The Control Room (CR) staff reacted to and mitigated the event in a professional and efficient manner. Communications within the "controls" area were clear and concise. Overall communications were hampered slightly by some interfering phone calls and unauthorized use of the radio channels. Communications between the Control Room and Field AOs included repeat backs and clarifications when appropriate.

Initial declaration of the Reactor Trip and notification of electrical distribution abnormalities were made by the Senior Reactor Operator-in Training (SRO/OJT) (utility, licensed). The event was correctly diagnosed as a Loss of Forced Circulation by the Control Room Supervisor (CRS) (utility, licensed). The appropriate procedures for event mitigation were applied. The emergency classification as a Notification of Unusual Event (NUE) was performed correctly by the Emergency Coordinator, although early termination of the NUE was made. Subsequent review of the EPIP-02 requirements for NUE Classification prompted the Emergency Coordinator to reinitiate the NUE concurrent with the 1E-NAN-S02 switchgear fire.

The Control Room operators were successful at maintaining their respective safety functions. Natural circulation was verified and maintained throughout the event. Plant stabilization, maintenance of adequate subcooled margin for greater than 12 hours, and subsequently, a slight cooldown were all achieved while on

natural circulation without incident.

Technical Specification requirements were addressed as required except as noted above. When problems such as the Startup channel and the Essential Chilled Water surveillances were identified they were dealt with properly. Minor problems in board indications or equipment response were identified and addressed properly. The primary operator's response to the loss of letdown, pressurizer level control, and maintenance of RCP seals was efficient. The secondary operator's response to ADV-179 control and MSIV-180 indication abnormalities was similarly effective. The Control Room Operators also promptly addressed the failure of the RCPs to restart. After considerable investigation, an action plan addressing the degraded 125 vdc bus voltage was developed and implemented to increase the available current and voltage on IE-NKN-M46.

Support Group performance was also professional and efficient. Problems i
their respective fields of expertise were identified
and addressed effectively. Initial response during the dayshift provided much needed support from the Protective Relaying and Control Group (PR&C), Engineering Evaluations Department (EED), and Fire Protection

Digital Fault Recorder (DFR) trace should have been reviewed. However, PR&C was available for consultation and support throughout the event. EED personnel, Mechanical and particularly Electrical, responded to the fire both expediently and professionally.

Excellent direction and control of the fire department's activities, as well as the number of personnel available to assist in firefighting, helped prevent a possibly much more severe event. In addition to the prudent activation of the OSC, the development of a technical liaison group by the EED Manager was beneficial in maintaining overall engineering support group perspective.

C. Status of structures, systems, or components that were inoperable at the start of the event that contributed to the event:

No structures, systems, or components were inoperable at the start of the event that contributed to the event.

D. Cause of each component or system failure, if known:

An evaluation was conducted to determine the Root Cause of Failure for 1E-NAN-S02. This inspection revealed that the original fault occurred in the "B" cubicle with blast damage into the "A" and "C" cubicles. Further inspection indicated that the fault initiated in the "B" phase and propagated to the "A" and "C" phases. Closer physical inspection of the damaged bus bar revealed two "bullet hole" point faults (one per bar) in the "B" phase bus directly adjacent to the support bar. This type of point fault is common for failures at this voltage, and it is postulated that they were the point of the original failure. It was noted that the bus insulation (Noryl) was cracked and brittle in the area of the point fault. Additionally, arc tracking was noted on the support bar adjacent to the point faults. Lastly, inspection of 1E-NAN-S02 showed build-ups of dirt on the floor of the "B" cubicle (1E-NAN-S01B contains similar material).

The initial fault current path was apparently from the "B" phase bus across the support bar to ground, which initiated a three-phase fault to ground. Although this is indicated by information obtained from the Digital Fault recorder, there was too much damage from the second fault to positively identify this.! Causal factors include degraded insulation and introduction of dirt and dust into the cubicle.

It has been determined that the most likely cause is a combination of:

1. Cracked and brittle Noryl insulation
2. Build up of dirt in the cubicles

Both of these conditions had to exist for this fault. These two problems allowed bus insulation breakdown and arc tracking. This eventually decreased the air gap to ground enough to cause a single phase (B phase) to ground. The resultant arcing propagated into a three phase to ground fault.

Evaluation has determined the causal factors that may have led to the failure of 1E-NAN-S02B. These factors include:

1. Possible inadequacies of the Preventive Maintenance (PM) task to identify the methods to properly clean the 13.8 kV switchgear, and

2. Operation of the 13.8 kV and 4.16 kV switchgear with less than adequate environmental or housekeeping controls.

A visual inspection of Unit 1 UAT was performed to determine the Root Cause of Failure. The preliminary inspection revealed that the failure appears to have developed in the H2Y winding, (the B phase High Voltage winding for the Y secondary! winding) in the bottom disk (the transformer is a pancake design). This apparently propagated the fault to ground, which precipitated the rupture and resultant fire. An engineering evaluation has been performed to determine the root cause of failure of the UAT. Based upon this evaluation the root cause is as follows.

The degree of damage from the internal fault, case rupture and subsequent fire precludes any positive identification of the cause of failure. The location of the failure was determined with reasonable certainty to be in the High Voltage (HV) winding, number 40 section or disc (from the top). This is an end HV disc associated with the Y2 winding. The failure was not caused from inadequate axial coil support since there was no indication of movement at coil ends. Additionally, there was no axial skewing of radial spacers. This indicates that the HV coils were wound with adequate tension in the conductors.

All evidence indicates that this failure began as a turn-to-turn failure which evolved into a multiple turn, multiple disc failure. The ampere turns of the remaining 39-38 discs were transformed to 1 or 2 discs. The localized fault current would rise to a very high value, several times the measured primary current (the 1 or 2 discs involved would appear as a single turn short). The concentrated fault quickly melted the wires in this area and the very high magnetic forces propelled the windings out.

The arc would then go to the tank, tap leads and adjacent phase leads. It is likely that the Sudden Pressure Relay and Differential Relay would have operated before this time. A few cycles after this

coil failure developed into a multiple phase fault, the ensuing gas bubble pushed the oil in all directions thereby rupturing the tank along 3 vertical corners and along the cover edge on the HV side.

Typically, a failure of this type does not leave enough evidence

to determine the cause of failure. From a design standpoint, these are very conservative transformers. Internal inspection of the spare UAT indicates very careful attention to detail. There is presently no reason to suspect anything but a singular material